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Effect of the Membrane Electrode Assemble Design on the Performance of Single Chamber Microbial Fuel Cells

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Abstract

Membrane electrode assemble (MEA) design is one of the crucial component of MFC. Therefore, the MEA design is critical to improving MFC's performance. In this work, effects of the presence of the cathode microporous layers and the distance between anode and cathode electrodes on MFC's performance are investigated. The experimental result indicates that the peak power density first decreases from 973 to 797 mW/m^2 when decreasing the distance from 2 to 1 cm, and then increases to 955 mW/m^2 when further reducing the distance to 0 cm. Meanwhile the ohmic resistance of the MFCs decreases from 34 to 14 and to 4.6 Ω with the reduced distance. This is because that the peak power density is improved by increasing the anode potential and decreasing the ohmic loss due to the reduced distance. However, when distance reduced from 1 to 0 cm, the decrease of cathode potential becomes the predominant factor. It is also found that the aerobic heterotrophic microorganism growing on the surface of both the proton exchange membrane and the anode electrode lowers the coulomb efficiency by consuming the organic substance. In addition, the presence of aerobic bacteria is the possible factor that induces the non-linear correlation between the ohmic polarization and electrodes distance.

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Keywords: Microbial fuel cells; Electrode distance; Ohmic resistance

1. Introduction

Based on the combination of biological treatment and electrochemical process, a newly developed technology termed microbial fuel cells (MFCs) has recently drawn extensive research interest owing to its high efficiency, low cost, environmental sustainability, ambient operating temperatures with biologically compatible materials, and added value byproducts such as electricity, fuels, and chemicals. MFCs has

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been a competive technology for wastewater treatment for different realistic wastewaters, including domestic, hospital, agricultural, animal, and oil mill wastewaters, et al[1,2]

The overall MFCs performance is significantly affected by many factors such as reactor configuration, electrode material, separator, electrolytes, microbial species, etc.[3,5]. It is generally considered that the power density will decline when the distance between the anodic and cathodic electrode is very small. So the membrane electrode assemble (MEA) design is critical to improve the cell performance. In this work, effects of the presence of the cathode microporous layers and the distance between anode and cathode electrodes on the cell performance are experimentally investigated.

2. Materials and methods

2.1. Construction of the MFCs

Single chamber air cathode MFCs were constructed. Carbon cloth (BASF Inc., USA) was cut into pieces with a projected surface area of 9 cm^2 and heat-treated to be the anode electrodes[4]. The air cathode was made of carbon paper (060, Toray Inc., Japan) with a micro porous layer (2.5 mg C/cm^2) and a platinum catalyst layer (0.4 mg Pt/cm^2) on the water side. Micro porous layer was made of carbon black (Vulcan XC-72) and 20 % wt PTFE by using spraying techniques. The catalyst layer was sprayed on micro porous layer by spraying coater.

Three different distances between anode and cathode electrodes (0 cm, 1 cm and 2 cm) of MFC with volume of 45mL start-up and operation were examined. The anode of MFC was inoculated with the outlet water from a long running MFC in fed batch mode and acclimated with a 1000 Ω resistor. All MFCs were placed in a thermostat incubator at 30 ℃ and fed with glucose (1 g/L) as substrate in a sodium phosphate buffer solution (PBS, 50 mM)[1].

2.2. Electrochemical tests

The voltages of the MFC across a 1000 Ω external resistor were recorded every 5 min with a multimeter and a data acquisition system (34970A, Agilent, USA). Current and power were normalized by the projected surface area of the anode. Coulombic efficiencies (CEs) were calculated assuming that total COD was removed in one cycle, which slightly underestimated CEs.

Electrochemical impedance spectroscopy (EIS) were tested with a potentiostat (Autolab PGSTAT302N, Metrohm Ltd., Switzerland). And the steady state potential was plotted as a function of current density. Internal resistance was characterized using EIS under open circuit voltage (OCV). The impedance measurements were carried out from 100 kHz to 10 mHz by applying a sine wave (10 mV) on top of bias potentials with a potentiostat. The ohmic resistance was determined by reading the real axis value at high-frequency intercept.

3. Result and Discussion

Figure 1 shows there were obvious differences among the maximum power density with different electrode distance under a single sludge inoculation. The MFC with 0 cm electrode distance generated cell voltage of 554 mV and maximum power density of 955 mW/m^2 (2.5 A/m^2). These datum were comparable to those obtained from MFC with 1 cm electrode distance (537 mV and 797 mW/m^2 (2.2 A/m^2) and MFC with 2 cm electrode distance (570 mV, 973 mW/m^2 at 2.9 A/m^2).

Figure 2 shows the effect of electrode distance on anode and cathode performance. The anode and cathode performance was examined by placing an Ag/AgCl reference electrode (0.195 V corrected to a normal hydrogen electrode; NHE) into the anodic chamber between the anode and cathode electrode. The MFCs with difference distances between anode and cathode electrodes had a similar change in working electrode potential: when increasing current density, the anode potential increased gradually, while the cathode potential decreased gradually.

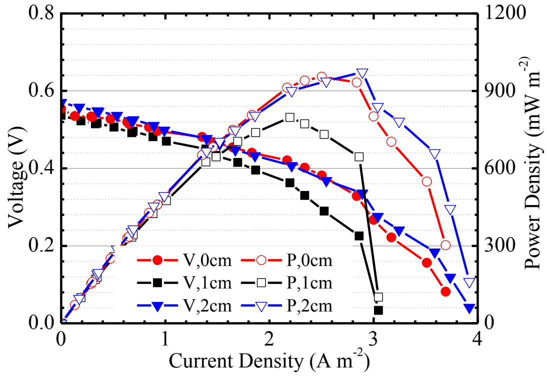

Fig.1 Polarization curves and power density curves with different electrodes spacing

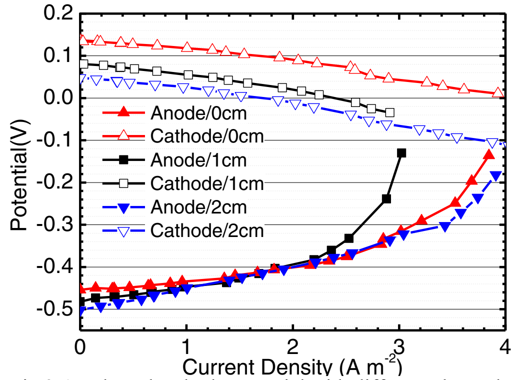

Fig.2 Anode and cathode potential with different electrode distances(vs Ag/AgCl reference electrode)

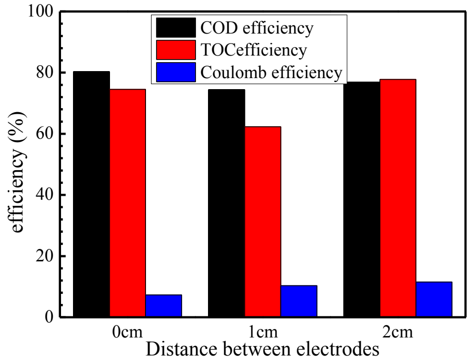

Fig.3 COD removal, TOC removal and Coulombic efficiency with different electrode spacing(1000 Ω)

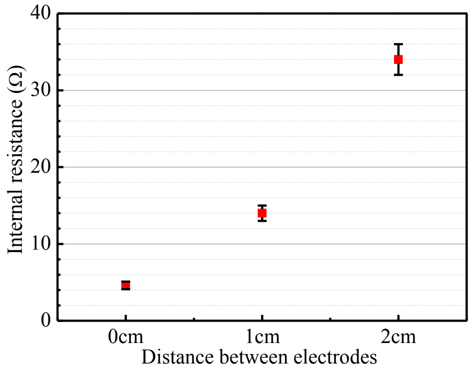

Fig.4 Internal resistance with different electrode spacing spacing

There were significant differences in the cathode potential among the different types of MFCs. The potential of the MFCs with 1 cm and 2 cm electrode distance were higher than that of MFC with 0 cm electrode distance at the same current density. Normally the aerobic bacteria growing on the anodic electrode (MFC with 0 cm electrode distance) or on the surface of proton exchange membranes and anodic room maintained the anode anaerobic environment. A possible reason for the different cathode potential among the three types of MFCs is that the aerobic bacteria between anaerobic bacteria with electrochemical activity and proton exchange membrane blocks the transfer of hydronium ion and that causes the potential of cathodic chemical reaction decreased slightly.

The anode potentials also had several differences among the three type of membrane electrode assemble, the anode potential of the MFC with 0 cm electrode distance increased slightly when current density increased from 0 A/m^2 to 4.0 A/m^2, while the potential of the MFCs with 2cm in electrode distance rapidly increased in a narrow range of current density from 0 A/m^2 to 3.6 A/m^2. Furthermore, the potential of MFCs with 1cm in electrode distance got most rapidly increased in the range of current density from 0 A/m^2 to 3.0 A/m^2, indicating severe polarization in the anode. This is because that the oxygen permeation through the Nafion 117 membrane affected the population of anaerobic bacteria with electrochemical activity on the anode electrode.

Figure 3 shows that Coulombic efficiency, COD removal efficiency and TOC removal efficiency when reduced the distance of electrodes. The Coulombic efficiency of the MFC with 2 cm electrodes distance was higher than the other two MFCs. Maybe this was caused by that the positive effect of electrochemical activity of anaerobic bacteria exceeded the negative effect of the aerobic loss of substrate, since these two effects have opposite contributions to Coulombic efficiency.

The internal resistances measured by EIS methode were shown in Figure 4. The change of the internal resistance shows that the reduction of distance between the anode and cathode can effectively reduce the ohmic resistance. Owning to the existence of aerobic bacteria in the anodic room, the ohmic polarization and electrodes distance shown a non-linear relationship In Fig. 4.

4. Conclusion

The redox potential of the anode is the factor for the difference of power density when the electrodes distance is 2 cm and 1 cm, but the redox potential of the cathode is also an important factor affecting the performance of MFC when the electrodes distance changes to 0 cm.

The aerobic heterotrophic microorganism growing on the surface of the proton exchange membrane and anodic electrode reduce the coulomb efficiency by consumption the organic substance.

Aerobic bacteria is the potential element that causes the non-linear relationship between the ohmic polarization and electrodes distance.

Acknowledgements

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Biography

Professor Ya-Ling He is currently the chief scientist for the National Key Basic Research Program of China (973 Program), the director of the Key Laboratory of Thermo-Fluid Science & Engineering of MOE and the head of Department of Thermal-Fluid Science and Engineering, Xi'an Jiaotong University.

Biography

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